The rhizosphere pH change of *Pinus koraiensis* seedlings as affected by N sources of different levels and its effect on the availability and uptake of Fe, Mn, Cu and Zn

CHEN Yong-liang, HAN Shi-jie, ZHOU Yu-mei

(Institute of Applied Ecology, Chinese Academy of Sciences, Shenyang 150016, P. R. China)

Abstract: Dark brown forest soil was collected from the upper 20 cm soil layer in Changbai Mountain Research Station of Ecosystem, Chinese Academy of Sciences. The soil was amended with two different forms of nitrogen fertilizers: NO_3^- as $Ca(NO_3)_2$, NH_4^+ as NH_4Cl at the concentrations of 50, 100, 200 and 400 mg kg^{-1} respectively. The experiment was carried out with 2-yr-old *Pinus koraiensis* seedlings in pot. The pH change of rhizosphere soil and the contents of available Fe, Mn, Cu, and Zn in soil and leaves were analyzed. The result indicated that the addition of NH_4^+-N decreased the rhizosphere pH value, while the addition of NO_3^--N increased the rhizosphere pH value in contrast with the control treatment. The direction and extent of the pH change mainly depended on N source and its concentrations applied. The rhizosphere pH change had a remarkable influence on the availability of the micronutrients in the rhizosphere, and thereafter affected the nutrient uptake by the seedlings. The contents of available mineral nutrients had a negative correlation with the pH value in the rhizosphere soil. The contents of available mineral nutrients in leaves were positively correlated to the levels of the available nutrients in the rhizosphere soils.

Keywords: Rhizosphere pH; N sources; Micronutrient; Availability; Uptake

CLC number: S714.8 **Document code:** A **Article ID:** 1007-662X(2002)01-0037-04

Introduction

Plants absorb water and nutrients directly from the zone, usually named rhizosphere soil, near the roots. This zone affects growth and product quality of the plants more obviously. Many researchers took interests in studying the characteristics of this zone, relative to the bulk soil (Marschner *et al.* 1986, 1987; Gahoonia *et al.* 1992a, 1992b; Hedley *et al.* 1994; Chen *et al.* 2001a). The manipulation of rhizosphere pH by using NH_4^+-N and NO_3^--N was pioneered by Riley and Baber, and later some researchers have shown that the availability and uptake of P, Fe, Mn, Cu, and Zinc depend on the rhizosphere pH (Sakar *et al.* 1982; Gillespie *et al.* 1990; Teng *et al.* 1995; Ruan *et al.* 2000; Chen *et al.* 2001b). However, the experimental materials in these studies mainly focused on the agricultural crops because of the difference of the research emphasis in subjects. This paper took the seedlings of *Pinus koraiensis*, one of the typical tree species in northern China, as the research object and systematically studied the rhizosphere pH change as affected by nitrogen form of different concentrations and its effect on availability and uptake of Fe, Mn, Cu and Zn.

Foundation item: This paper was supported by National Natural Science Foundation of China (Grant No. 30170167).

Biography: CHEN Yong-liang (1969-), male, Ph. Doctor, lecture of Northeast Forestry University, Harbin 150040, Post-doctor in Institute of Applied Ecology, Chinese Academy of Sciences, Shenyang 110016, P. R. China. E-mail: ylchin@sohu.com

Received date: 2002-01-12

Responsible editor: Song Funan

Materials and methods

Dark brown forest soil was taken from Changbai Mountain Research Station of Ecosystem, Chinese Academy of Sciences. It was collected from the upper 20 cm soil layer after the litter was removed. The soil was air-dried, and stones and dead fine roots were removed by a 2-mm sieve. The general physical and chemical properties of the soil were analyzed by the standard methods issued by the State Standard Bureau. Then the soil was amended with two different forms of nitrogen fertilizers: NO_3^- as $Ca(NO_3)_2$, NH_4^+ as NH_4Cl at the concentrations of 50, 100, 200 and 400 mg·kg^{-1} oven dry soil respectively. A control experiment without nitrogen addition was included at the same time. All nutrients were added as solutions and were completely mixed with the soil. The nitrification inhibitor dicyandiamide (DCD) was mixed with the soil in all treatments at a rate of 60 mg·kg^{-1} in order to prevent conversion of NH_4^+ to NO_3^-.

The experiment was carried out with two years old *Pinus koraiensis* seedlings. Every treatment was replicated five times and arranged in a randomized complete block in a greenhouse. The soil was kept at about 80% field capacity by regular watering with distilled water. At the end of the 12th week, rhizosphere soil samples were obtained by peeling the soil directly adhering to seedling roots with a small brush. The seedlings were harvested and divided into roots, stems and leaves and dried at 70 °C. Finally, the soil samples were analyzed for pH, available Fe, Mn, Cu, and Zn, and the leaves were also analyzed for the contents of Fe, Mn, Cu and Zn. All analyses were carried out by stan-

dard methods issued by the State Standard Bureau.

Results and discussion

The pH change in rhizosphere soil

The rhizosphere soil pH change as affected by N sources of different concentrations is given in Fig. 1. The addition of NH_4^+-N decreased the rhizosphere pH, while the addition of NO_3^--N increased the rhizosphere pH, in contrast with the control treatment. This phenomenon indicates that the direction of the pH change mainly depends on nitrogen source applied. The form in which nitrogen is absorbed by plant largely determines the acidifying or alkalizing effects of plant rhizosphere. From ionic balance studies, when being applied mainly with NH_4^+-N, the plant accumulated more positive charges in it and could always excrete H^+ to keep the charge balance in it. On the contrary, when being given mainly with NO_3^--N, the plant accumulated more minus charges in it and could always give rise to OH^- or HCO_3^- excretion. It is concluded that ammonium nutrition could always lead to the increase of H^+ excretion, thus decreased the rhizosphere pH, while nitrate nutrition could always give rise to OH^- or HCO_3^- excretion and increased the rhizosphere pH. The pH changes of rhizosphere will certainly affects the availability of nutrient elements in rhizosphere soil.

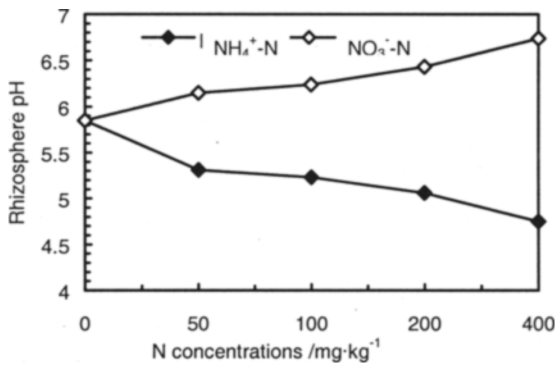
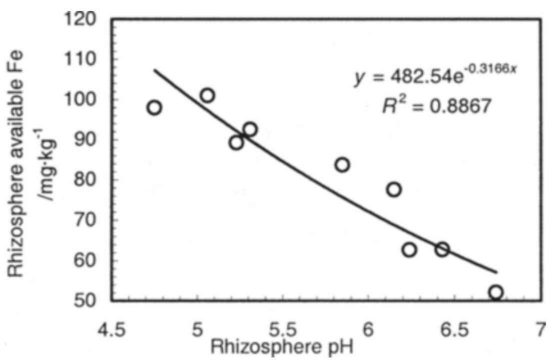


Fig. 1 The pH change of rhizosphere of *Pinus koraiensis* seedling as affected by N sources of different concentrations

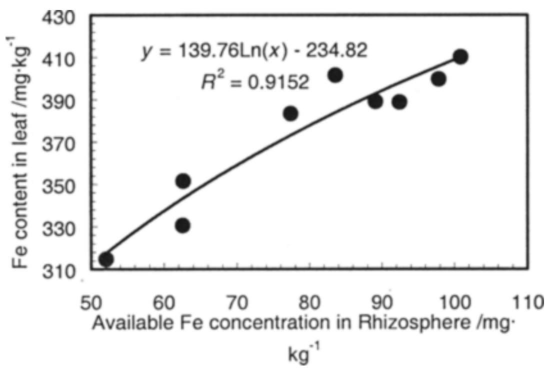
The extent to which the rhizosphere pH decreased or increased was correlated to the concentrations of nitrogen sources added. On the other hand, the extent to which the rhizosphere pH decreased on account of the addition of NH_4^+-N was bigger than that to which the pH increased by using NO_3^--N. Generally speaking, the assimilation of NH_4^+-N after absorption was finished mainly in the roots and the proton number released is almost equivalent to that of NH_4^+-N absorbed. However, the assimilation of the NO_3^--N is proceeded partly in the roots and partly is transferred to the shoots and assimilated, so that the number of the OH^- or HCO_3^- released is usually less than that of NO_3^--N absorbed. In the control treatment, the rhizosphere pH was 5.85. In the NH_4^+-N treatment, the rhizosphere pH was 5.31, 5.23, 5.06, and 4.75, respectively at different NH_4^+-N concentrations of 50, 100, 200, and 400 mg·kg^{-1}. In the NO_3^--N treatment, the rhizosphere pH is 6.15, 6.24, 6.43, and 6.74 respectively at same concentrations with those of NH_4^+-N. So a pH gradient is produced by the addition of N source of different levels. The altered rhizosphere pH will certainly affect the availability of the mineral nutrients, especially the micronutrients in the rhizosphere soil and thereafter influence the uptake by the seedlings.

Effect of pH change on the availability and uptake of micronutrients

The changed rhizosphere pH had a remarkable influence on the availability of micronutrients (Fe, Mn, Cu, and Zn) in the rhizosphere soil and thereafter affected the changed levels of available micronutrients on uptake by seedlings (See Fig. 2-5). The concentrations of the available Fe, Mn, Cu and Zn in the rhizosphere soils decreased when the rhizosphere pH increased on account of the addition of NO_3^--N, but increased when the rhizosphere pH decreased by adding NH_4^+-N. The contents of available mineral nutrients had a negative correlation with the pH value in the rhizosphere soil. The nutrient contents of the Fe, Mn, Cu and Zn in leaves were positively correlated to the levels of the available nutrients in the rhizosphere soils.



(A)



(B)

Fig. 2 Effect of pH change on the Fe availability in the rhizosphere (A) and effect of available Fe levels in the rhizosphere soil on Fe content in leaves (B)

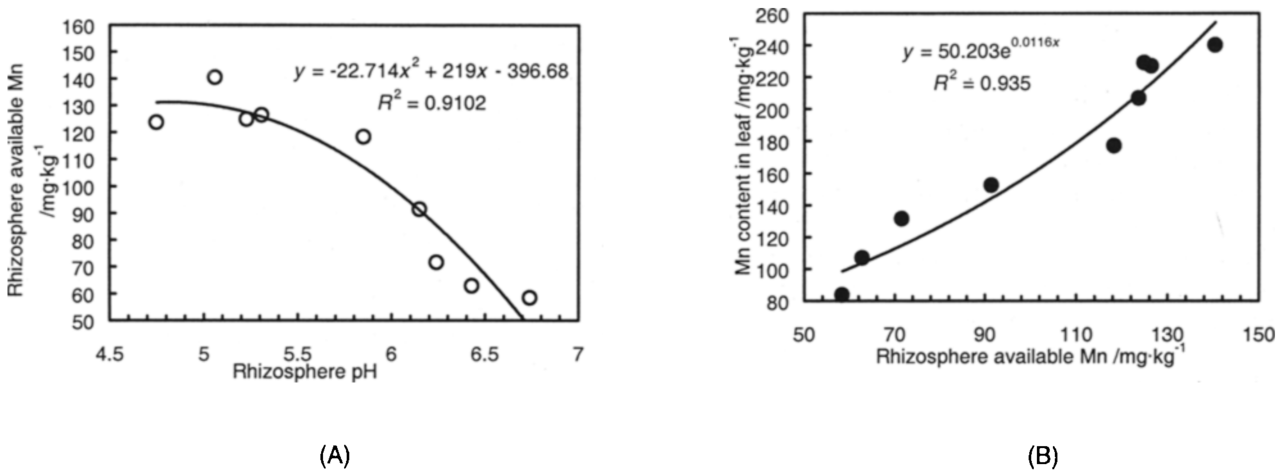


Fig. 3 Effect of pH change on the Mn availability in the rhizosphere (A) and effect of available Mn levels in the rhizosphere soil on Mn content in leaves (B)

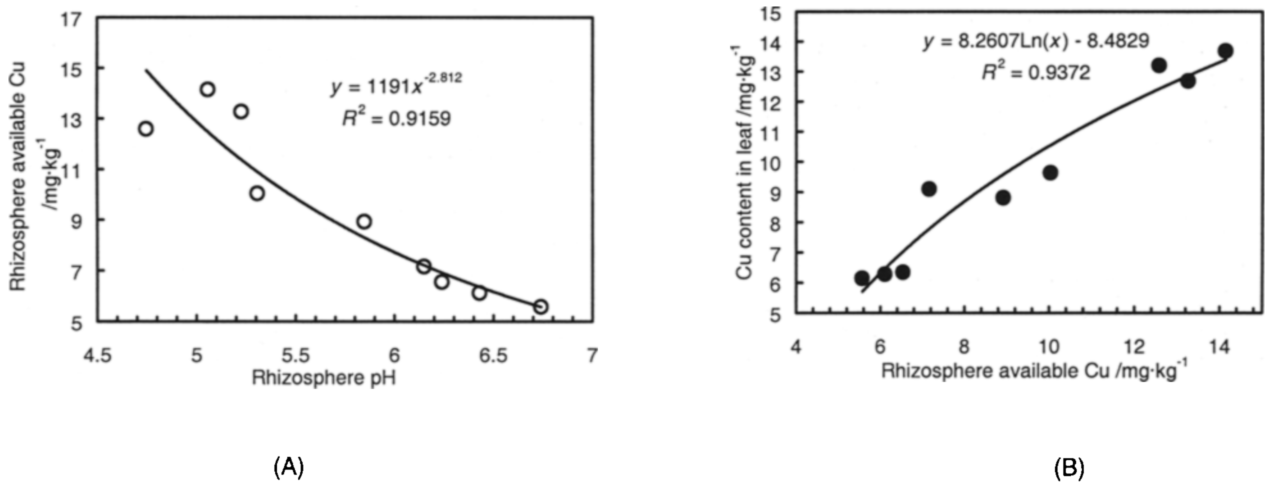


Fig. 4 Effect of pH change on the Cu availability in the rhizosphere (A) and effect of available Cu levels in the rhizosphere soil on Cu content in leaves (B)

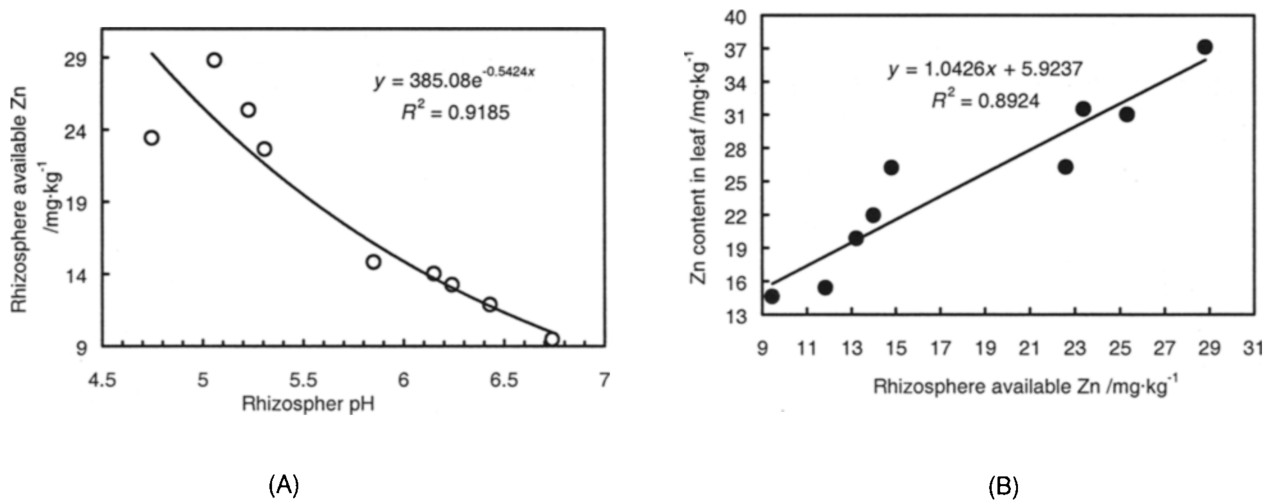


Fig. 5 Effect of pH change on the Zn availability in the rhizosphere (A) and effect of available Zn levels in the rhizosphere soil on Zn content in leaves (B)

References

Chen Yongliang and Han Shijie. 2001. Nutrient characteristics in the rhizosphere of pure and mixed plantations of Manchurian walnut and Dahurian larch [J]. Journal of Forestry Research, **12**(1): 18-20.

Chen Yongliang and Han Shijie. 2001. The pH change in rhizosphere of *Pinus Koraiensis* as affected by different nitrogen sources and its effect on phosphorus availability [J]. Journal of Forestry Research, **12**(4): 249-249.

Gahoonia, T.S. and Nielsen, N.E. 1992. Mobilization of phosphate in different soils by ryegrass supplied with ammonium or nitrate [J]. Plant Soil, **140**: 241-248.

Gahoonia, T.S. and Nielsen, N.E. 1992. Effect of root-induced pH changes on the depletion of inorganic or organic phosphorous in the rhizosphere [J]. Plant Soil, **143**: 185-191.

Gillespie, A.R. and Pope, P.E. 1990. Rhizosphere acidification increases phosphorus recovery of black locust: Ⅰ. Induced acidification and soil response [J]. Soil Sci. Soc. Am. J., **55**: 533-537.

Hedley, M.J., Kirk, G.J.D. and Santos, M.B. 1994. Phosphorus efficiency and the form of phosphorus utilised by upland rice cultivars [J]. Plant Soil, **158**: 53-62.

Marschner, H., Host, W.J., Martin, P. and Romheld, V. 1986. Root induced changes in the rhizosphere: Importance for the mineral nutrition of plants [J]. Z. Pflanz. Bodenk., **149**: 441-456.

Marschner, H., Romheld, V. and Cakmaek, I. 1987. Root induced changes in the nutrient availability in the rhizosphere [J]. J. Plant Nutr., **10**: 1175-1184.

Sarkar, A.N. and Jones, R.G. 1982. Effect of rhizosphere pH on the availability and uptake of Fe, Mn, Cu and Zn [J]. Plant Soil, **66**: 361-372.

Teng, Y. and Timmer, V.R. 1995. Rhizosphere phosphorus depletion induced by heavy nitrogen fertilization in forest nursery soils [J]. Soil Sci. Soc. Am. J., **59**: 227-233.

Thomson, C.J., Marschner, H. and Romheld, V. 1993. Effect of nitrogen fertilizer form on pH of the bulk soil and rhizosphere, and on the growth, phosphorus and micronutrient uptake of bean [J]. J. Plant Nutri., **16**: 493-506.